Elettra, the new light

SINCROTRONE TRIESTE

Synchrotron radiation

An electrically charged particle entering a region of space where a magnetic field is present, deviates from its original straight trajectory and, as a consequence, emits energy in the form of electromagnetic waves. As the speed of an electron beam approaches the speed of light, this radiation is emitted in a very narrow cone pointing along the tangent of its trajectory. This phenomenon was casually observed for the first time with the naked eye in 1947 inside a synchrotron of the General Electric Company in Schenectady and since then the electromagnetic radiation has been named **synchrotron light** or **synchrotron radiation**.

From being simply a curiosity, synchrotron radiation, with its properties of being very intense, highly collimated and with a large spectrum of wavelengths (comparable with the dimension of atoms, molecules and macromolecules) has become more and more relevant as a means for investigating the structure of materials of any type.

Compared to traditional sources, which emit only a few isolated wavelengths above a weak continuous background, synchrotron radiation covers a large spectrum of wavelengths, from the ultraviolet to the X-ray region. In this way it is possible to select a well defined wavelength and use it for a specific experiment.

As a follow up of the success achieved in many fields of science & technology — as for instance biology, chemistry, physics, medicine, materials science — by using synchrotron radiation emitted as an unwanted by-product of high energy physics machines, the so called «second generation» machines dedicated to the production of synchrotron radiation were designed and built from the mid 70's onwards. Recently, with the invention of wigglers and undulators, «third generation» machines optimized to exploit these new sources of light have been designed in Berkeley (USA), Grenoble (France) and Trieste.

Synchrotron light is an interdisciplinary research tool providing an important meeting point between fundamental and applied research, between scientists and industrial researchers. It will therefore be a source of industrial development for Trieste, the Region Friuli Venezia Giulia and our Nation.

The Trieste synchrotron light source will be one of the most advanced in the world and it will promote Trieste as a real scientific pole, starting point for new initiatives with wide prospects of economical spin-off in the Region.

The Italian government, the Region Friuli Venezia Giulia and the Research Area of Trieste have created a new flexible tool in order to realize this enterprise and have provided suitable financial resources.

Our commitment is to build the machine and the beamlines complying with the time schedule so as to face, without any delay, the challenging and fascinating competition that is waiting for us.

Prof. Carlo Rubbia, Nobel Laureate
President of Sincrotrone Trieste S.p.A.

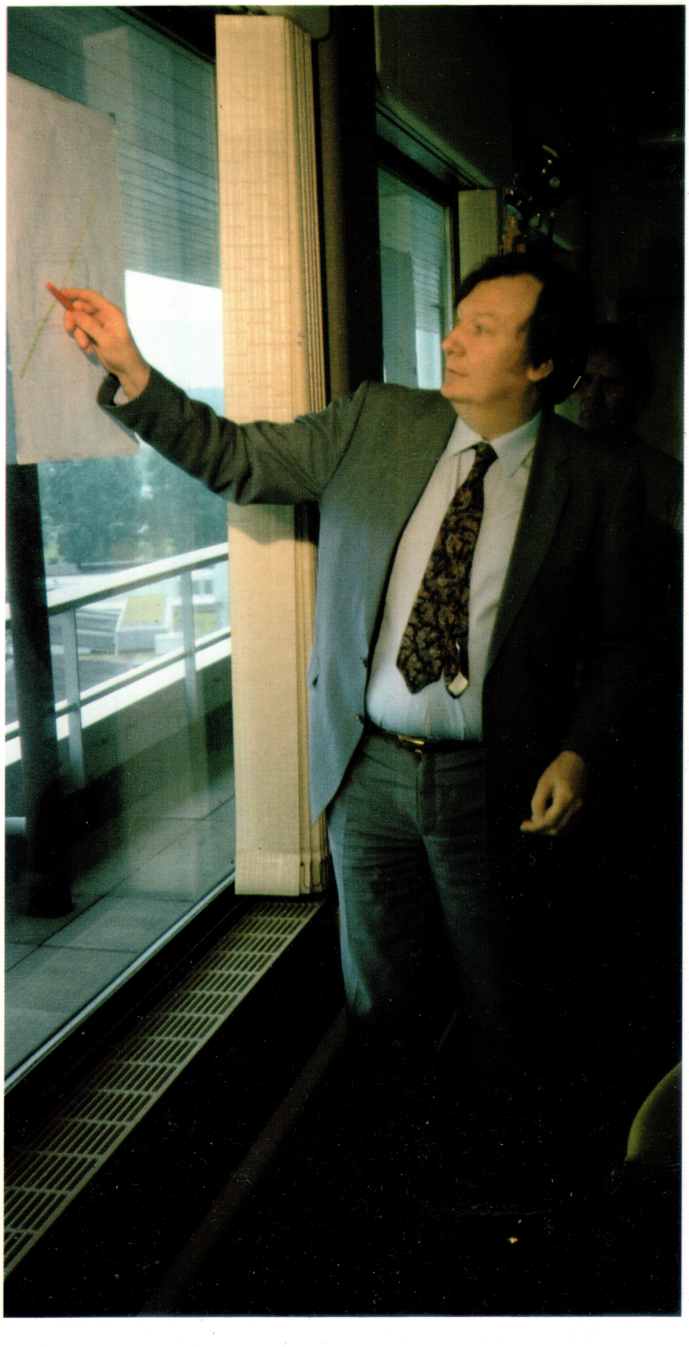

Fig. 1 A possible experimental station at the end of a beam line.

Fig. 2 Typical diffraction pattern obtained in the crystallographic study of proteins.

Fig. 3 From the diffraction pattern, the reconstruction of the spatial structure is carried out by computer, as shown in this case for the poliomyelitis virus.

Elettra, the new light

The ELETTRA project started in April 1987 and its completion is planned for the year 1993. For ELETTRA, two accelerators will be built. The first one constitutes the injection system, the second is a storage ring which represents the actual light source. The electrons, generated by a thermionic source, are accelerated up to an energy of 1.5 GeV* by a linear accelerator (*Linac*). From the *Linac* the electrons, grouped in bunches, are transferred to the storage ring - which is a synchrotron whose magnetic field is maintained constant - where the electron beam circulates with constant energy for a period of many hours with decreasing intensity, until the injection procedure has to be repeated.

The storage ring will have a circumference of about 260 meters with 12 straight sections, to accomodate undulators and wigglers, joined together by 12 arcs where the bending magnets will be installed.

The electron bunches are moving in a vacuum chamber made out of stainless steel with a cross section of about 40 square centimeters. On their way through the vacuum chamber, with a speed comparable to the speed of light, the electron bunches will interact with the magnetic fields generated by the bending magnets, undulators and wigglers, and will emit synchrotron light.

ELETTRA is optimized for the use of wigglers and undulators. These multipole magnetic devices are installed in the straight sections of the storage ring. They are made out of two parallel rows of magnets producing a magnetic field perpendicular to the direction of the electron beam with alternating polarity; the electrons are forced to move on a wiggling orbit. Inside the wigglers, the light is emitted incoherently and its total intensity is 2N times the intensity obtained from a bending magnet, where N in the number of the wiggler's periods. In the undulators, the oscillations of the electron beam are slight, so that we obtain an interference between the electromagnetic waves emitted by the

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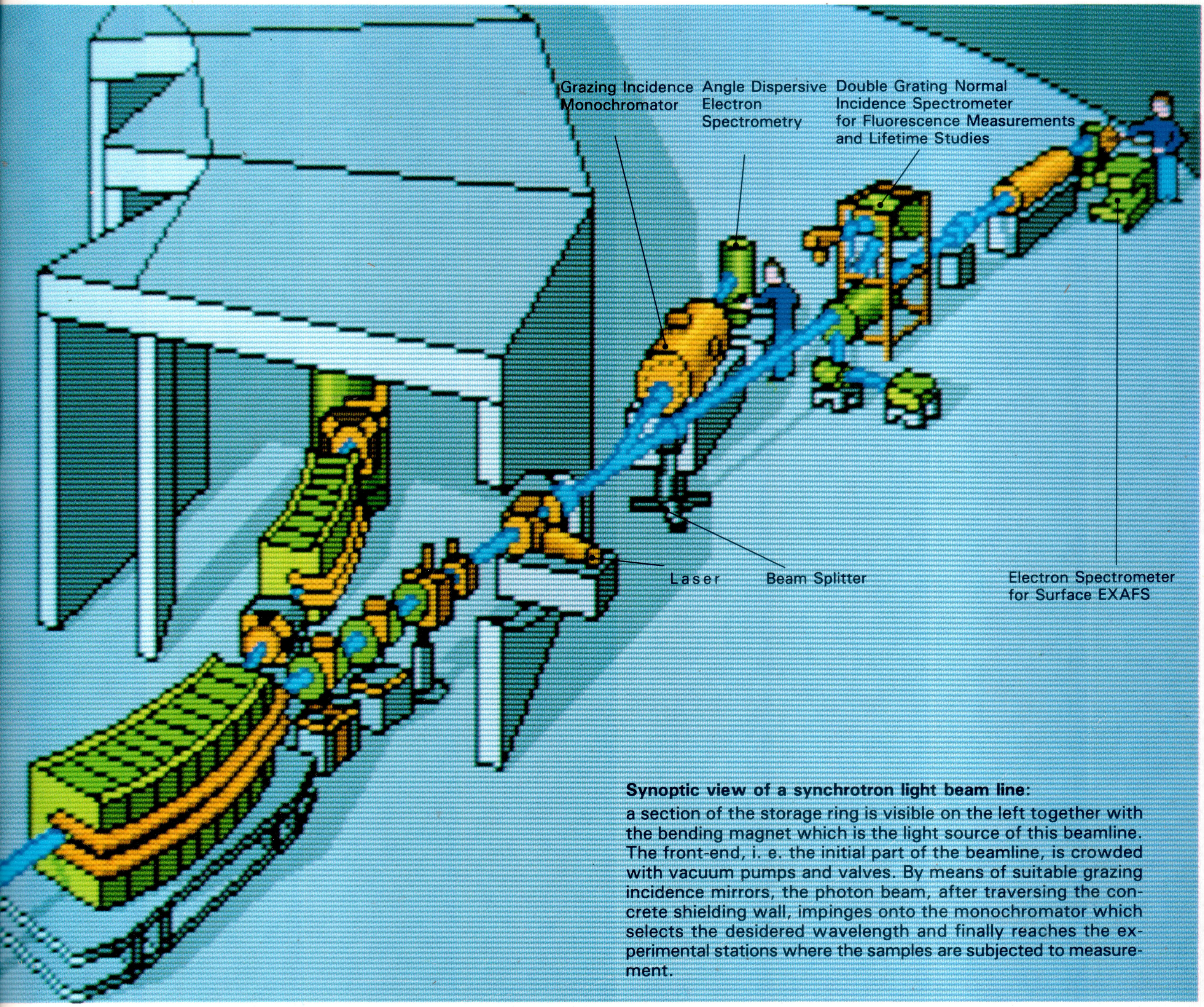
* 1 GeV corresponds to one billion electronvolts.


Grazing Incidence Monochromator
Angle Dispersive Electron Spectrometry
Double Grating Normal Incidence Spectrometer for Fluorescence Measurements and Lifetime Studies
Laser
Beam Splitter
Electron Spectrometer for Surface EXAFS

Synoptic view of a synchrotron light beam line:
a section of the storage ring is visible on the left together with the bending magnet which is the light source of this beamline. The front-end, i. e. the initial part of the beamline, is crowded with vacuum pumps and valves. By means of suitable grazing incidence mirrors, the photon beam, after traversing the concrete shielding wall, impinges onto the monochromator which selects the desidered wavelength and finally reaches the experimental stations where the samples are subjected to measurement.

same electron from the various curved parts of its trajectory. The spectrum of the very brilliant light obtained is composed of one or several narrow bands. The brillance of the radiation, that is the capability of concentrating on samples of very small dimensions an intense flux of monochromatic photons coming from Elettra undulators, will be, in the wavelenght interval ranging from ultraviolet to soft X-rays, the highest in the world, 100 to 1000 times higher than the brilliance achieved by similar machines currently under operation in the US (Brookhaven, Stanford), in Europe (Berlin, Daresbury, Frascati, Orsay) and in Japan (Tokyo, Tsukuba). The increase in brilliance will allow an enormous qualitative leap in the field of experimental science with the real possibility of opening new horizons and of making new scientific discoveries, unthinkable to-day, to the benefit of our society.

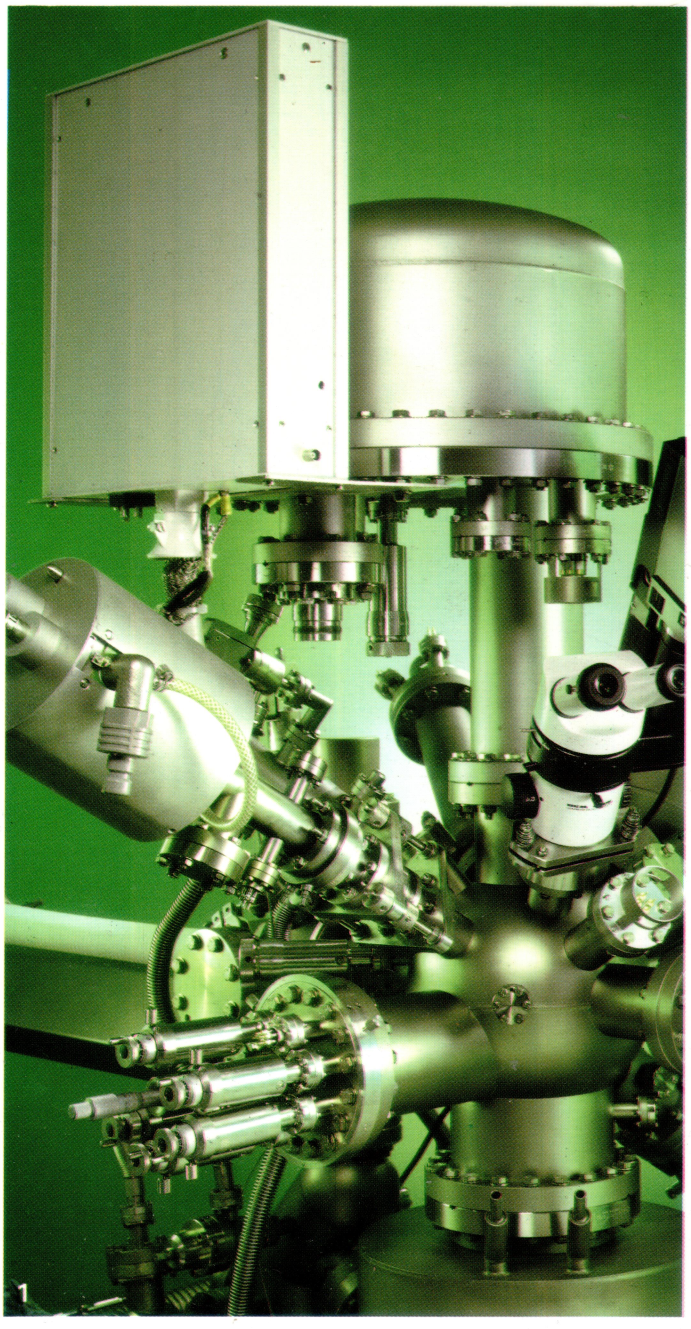
It will allow the performance of experiments which are not feasible today, with extremely short exposure times.

Another characteristic property of the light emitted by ELETTRA will be its time structure. Because of the bunching of the electron beam, the emission of light will be pulsed with an accuracy and stability of a quartz watch. This will allow the performance of experiments aimed at obtaining an understanding of kinetic and dynamic properties of biological and chemical systems.

In order to build and operate ELETTRA, a share holding company, Sincrotrone Trieste, was founded. An allocation of funds of 150 billion lire, has been foreseen by the governmental economic program committee CIPE, 75 billion lire given by the State, 45 given by the Research Area and 30 given by the Regional Administration.

At Sincrotrone Trieste about 150 people, including scientists, technicians and administrators, will eventually work. It is foreseen that about 2000 scientists and industrial researchers, coming from many nations, will use the facility every year.

The project leader of ELETTRA is Mario Puglisi, his deputy Albin Wrulich, the scientific director Luciano Fonda and Renzo Rosei the deputy scientific director.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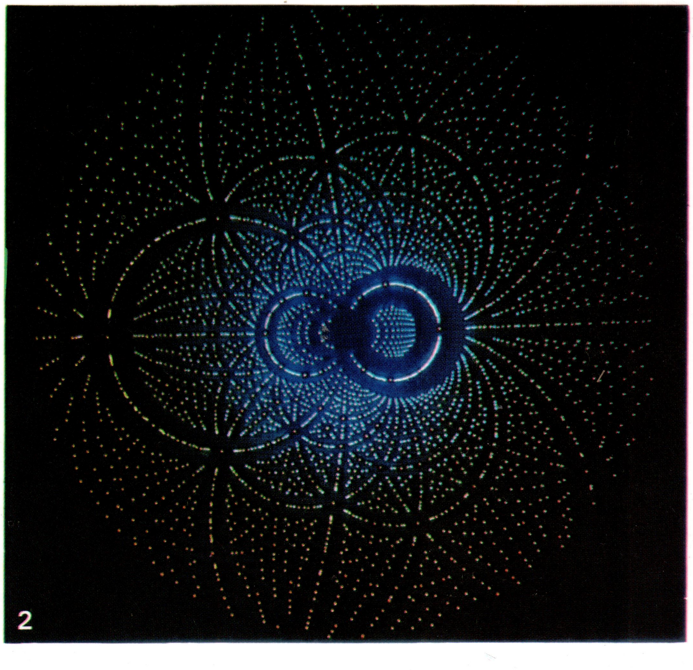
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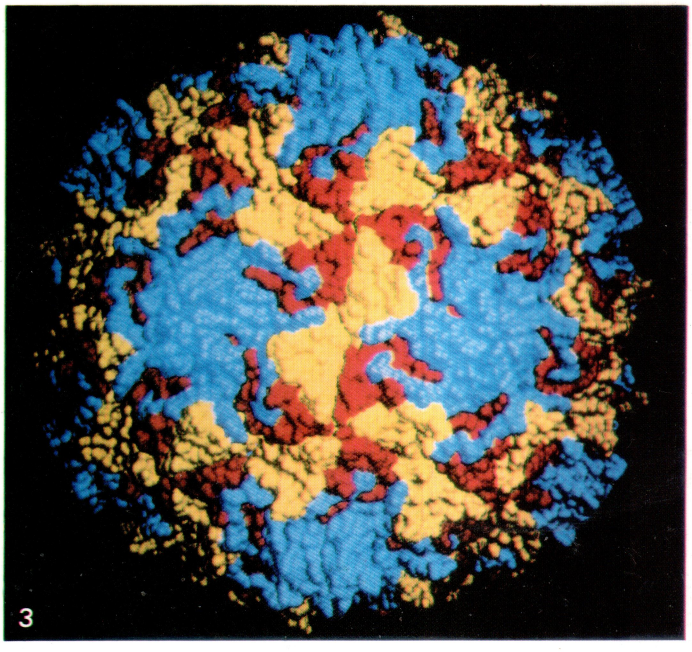
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Some applications

The synchrotron light emitted from the various sources placed in the storage ring (undulators, wigglers, bending magnets) is brought, by means of suitable beamlines under ultra-high vacuum conditions, to the experimental areas where it is used to analyze the structure of sample materials.

Here is a short review of possible applications:

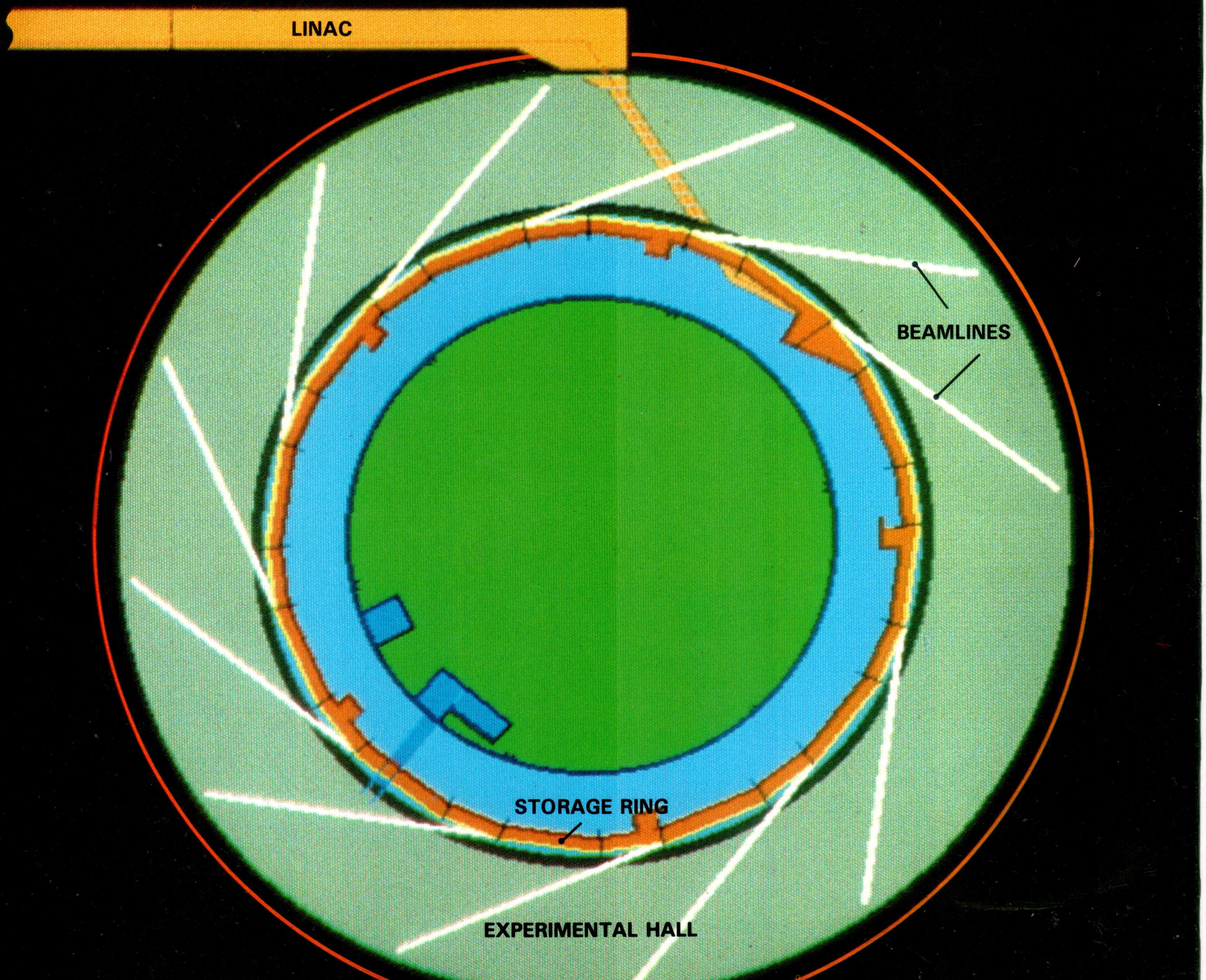
From the EXAFS technique, which consists in the analysis of the fine structure of the X-ray absorption spectra of materials, it is possible to obtain information about the position of the absorbing atom with respect to the neighboring atoms, of which number and atomic species can be determined. By means of the increased brilliance of ELETTRA's radiation, it will be possible to follow the dynamic changes occuring in the structure of the materials involved, which are provoked for instance by chemical reactions, with applications in the fields of catalysis, surface corrosion and in the study of active sites of enzymes and proteins.

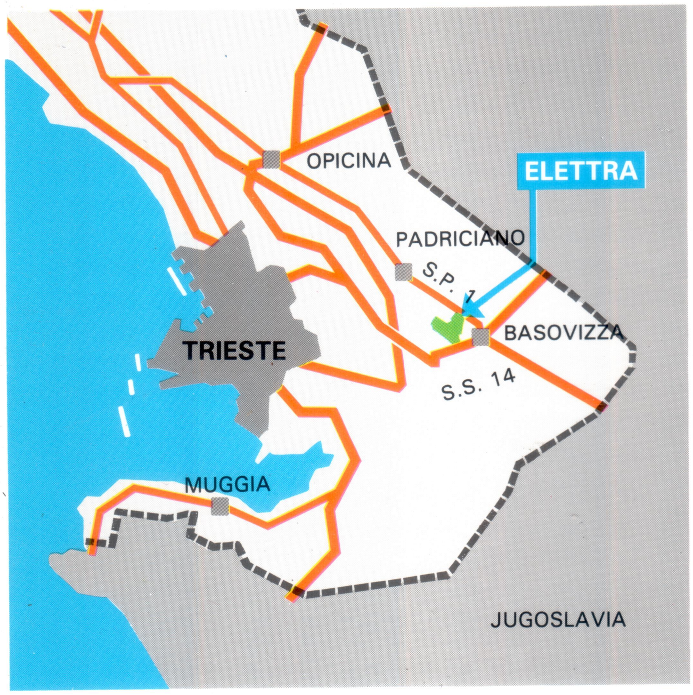
Another experimental technique, photoemission, which exploits the well known phenomenon of the photoelectric effect — the emission of electrons by materials which are struck by light — can reveal details of the behaviour of the electrons belonging to semiconducting materials, so helping the development of more advanced electronic devices. By means of a related technique (ESCA) detailed information will be obtained about the structure and composition of materials of great technological interest. In addition, a great diagnostic aid will be given to the metallurgy industry, from the ability to perform accurate analyses of structural defects (grain boundary segregation, microinclusions, etc.) with spatial resolutions of the order of one tenth of a micron. The photoemission technique, combined with the possibility of measuring the spin polarization of the electrons emitted by the material under investigation, will help us in the understanding of some still obscure magnetic phenomena. These developments will allow a big leap in the industrial field of data storage (computers, videotapes, etc.).

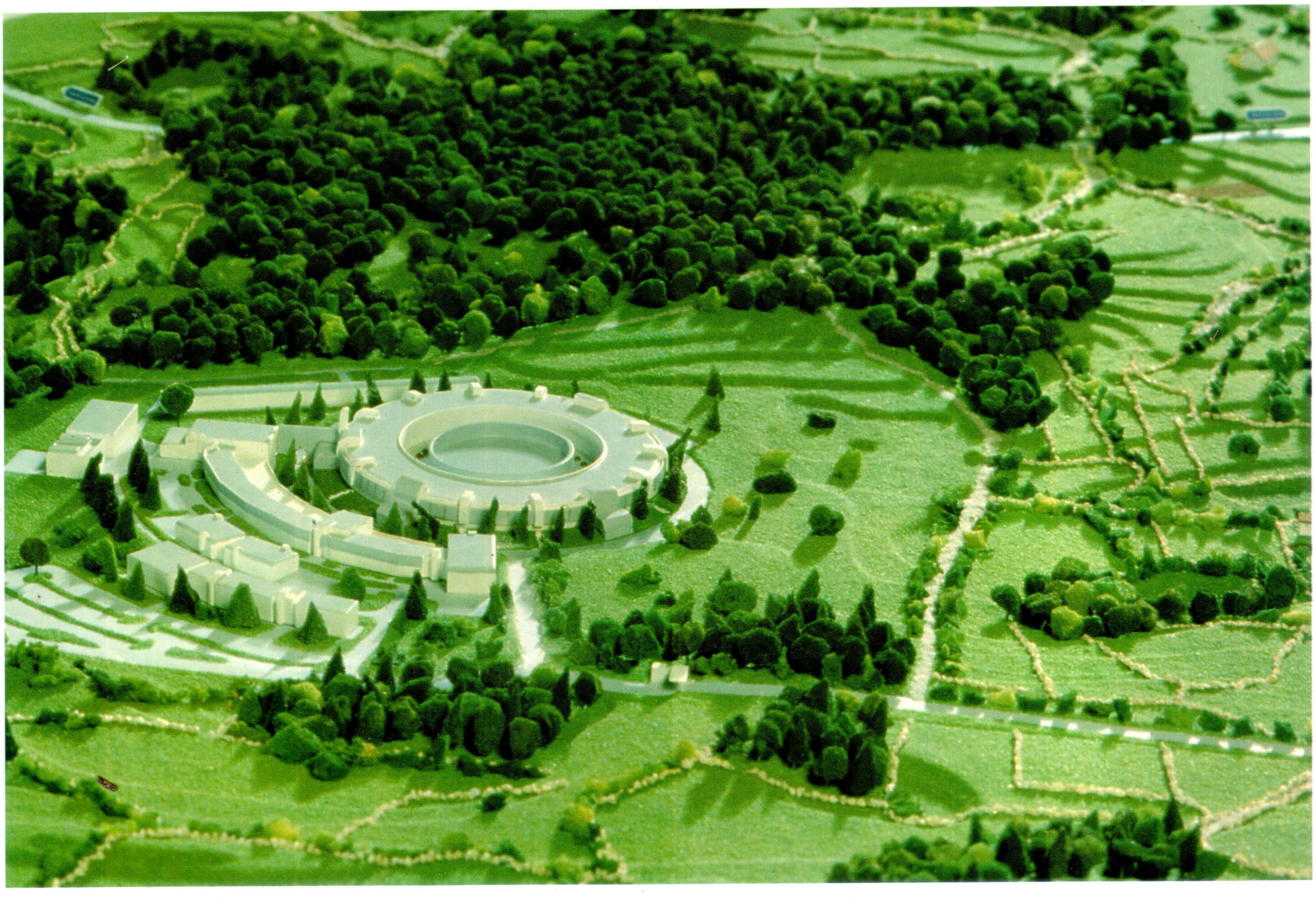
X-ray microscopy, now rapidly developing, will be applied to the study of cells. In particular, as a very fast data-acquisition will be available, it will be possible for example to film live cells; this is impossible with conventional techniques, using the electron microscope.

Crystallography is another field which is in great development thanks to the use of synchrotron radiation. By means of this diffractometric technique, the form and the chemical composition of some proteins and viruses will be determined. The impact of these scientific discoveries in relation with human health will be enormous.

Layout of the accelerators and of the experimental hall.







The site presents excellent geological and morphological characteristics. It has an area of 45,8 hectares, of which more than half is dedicated to environmental preservation and agricultural use. Of the remaining part, only 3 hectares are reserved for construction.

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Share holders:
Research Area of Trieste
Friulia - financial company of Friuli Venezia Giulia Region
S.P.I. - Sviluppo Promozione Imprenditoriale - I.R.I. group
E.N.I. Ricerche

Company's capital: 55.000.000.000 lire

Board of directors:
President: Carlo Rubbia
Vice president: Sergio Tripani
Managing Director: Giuseppe Viani
Members of the Board: Fulvio Anzellotti, Alessandro Brenci, Gianfranco Chiarotti, Luigi Croce, Emilio Picasso, Carlo Rizzuto, Domenico Romeo, Sergio Tazzari, Romualdo Volpi

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